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Mesquite pod meal in sheep diet: intake, apparent digestibility of nutrients and nitrogen balance

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ABSTRACT. Eight Santa Ines sheep were assigned to two 4 x 4 Latin squares, to evaluate the effects of replacing elephant grass silage with different levels of mesquite pod meal (MDM) (15, 30 and 45% DM) on intake, apparent digestibility of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), acid detergent fiber (ADF), neutral detergent fiber (NDF), total carbohydrates (TC) and non-fiber carbohydrates (NFC) and the nitrogen balance. There was a linear increase ($p < 0.05$) in the intake of DM, OM, CP, ADF, NDF, NFC and TC according to the addition of MPM to the diet. The digestibility of DM, OM and CP increased ($p < 0.05$) with the addition of MDM. We observed a positive linear effect ($p < 0.05$) for the nitrogen intake. The addition of mesquite pod meal up to 45% increased the intake of DM, NDF, ADF, CP, OM, NFC and TC but reduced the digestibility of EE and NDF. MPM at 30 and 45% propitiated a positive nitrogen balance.

Keywords: forage conservation, *Prosopis juliflora*, silage.

Farelo de vagem de algaroba em dietas de ovinos: consumo, digestibilidade aparente dos nutrientes e balanço de nitrogênio

RESUMO. Foram utilizados oito ovinos da raça Santa Inês, distribuídos em dois quadrados latinos 4 x 4, com o objetivo é avaliar os efeitos da adição do farelo de vagem de algaroba - FVA (15, 30 e 45% da MS) em substituição à silagem de capim elefante sobre o consumo, digestibilidade aparente da matéria seca (MS), matéria orgânica (MO), proteína bruta (PB), extrato etéreo (EE), fibra de detergente ácido (FDA), fibra em detergente neutro (FDN), carboidratos totais (CT) e carboidratos não fibrosos (CNF) e balanço de nitrogênio. Foi observado efeito linear crescente ($p < 0,05$) dos níveis de FVA sobre os consumos de MS, MO, PB, FDA, FDN, CNF e CT. Os coeficientes de digestibilidade da MS, MO e PB aumentaram ($p < 0,05$) com a adição de FVA. Observou-se efeito linear positivo ($p < 0,05$) para a ingestão, excreção fecal e retenção de nitrogênio, enquanto que a excreção de N na urina não variou ($p > 0,05$) em função dos níveis de substituição. A adição de FVA em até 45% proporcionou o aumento do consumo de MS, FDN, FDA, PB, MO, CNF e CT, mas, reduziu o coeficiente de digestibilidade do EE e de FDN. Os níveis 30 e 45% de FVA proporcionaram balanço de nitrogênio positivo.

Palavras-chave: conservação de forragem, *Prosopis juliflora*, silagem.

Introduction

In Brazil, an increasing number of sheep is found in the Northeast region driven by growing demand for sheep meat in the domestic market. However, the growth performance of these animals in this region is low, because the exploration system adopted is mainly extensive, in which feed intake is usually not sufficient to meet the nutritional requirements of sheep to achieve high performance.

Food consumption is highly correlated with its nutritional composition and digestibility, since the dry matter intake increases with increasing digestibility until the animal is satiated occurring for that a physiological regulation. According to Maggioni et al. (2009), consumption is directly related to the degradability and digestibility of cell wall of the food and its rate of passage through the digestive tract.

The use of conserved forage is an alternative for tropical regions that, due to seasonality, suffer from food shortage for animals, weight loss and reduced performance, which consequently result in longer stay of the animal in the herd. Upon cutting, the low availability of soluble carbohydrates in the forage can affect the nutritional quality of the silage due to lack of substrates for the appropriate activity of microorganisms that produce lactic acid, which can further reduce the intake.

In accordance with Minson (2012), fermentation products such as acetic and lactic acids are responsible for the reduced consumption of silage compared to other forages, for example, hay, besides factors as the physical change of the ensiled material, production of ammonia and pH reduction. In contrast, legumes have a higher consumption, are less resistant to particle breakdown during mastication and rumination.

Mesquite is a legume widespread in the Northeast region and has attracted attention because of its excellent nutritional value, being a rich energy source (Silva et al., 2001), and for this reason it has been extensively studied (Ali et al., 2012; Girma et al., 2012; Pereira et al., 2013). Generally, mesquite pods (*Prosopis juliflora*) are transformed into meal and then used for animal feed, being an interesting option for sheep feeding in the dry period.

Given the above, this study evaluated the replacement of elephant grass silage (*Pennisetum purpureum*) with mesquite pod meal (*Prosopis juliflora*) on intake, digestibility and nitrogen balance.

Material and methods

The experiment was conducted at the Laboratório de Ensaios Nutricionais de Ovinos e Caprinos and Unidade Experimental de Caprinos e Ovinos of the Universidade Estadual do Sudoeste da Bahia, Campus Juvino Oliveira in Itapetinga, Bahia State. Eight Santa Ines adult sheep, unneutered males, with an average body weight of 32 kg and average age of six months were housed in metabolic cages (0.8 m^2) with access to individual feeders, drinkers and salt and distributed into two 4 x 4 balanced Latin squares, with four periods of 15 days each, considering ten days of adaptation and five for data collection. Treatments consisted of the partial replacement of elephant grass silage with 15, 30 and 45% mesquite pod meal (MPM) in the total dry matter of the diet. A diet containing only elephant grass silage was the control treatment.

Animals were fed twice a day (7h00 am and 4h00 pm). Daily leftovers were collected and weighed, so that the leftovers were kept to a percentage close to 10% of diet on a fresh matter basis. Daily intakes were determined by the difference between the total diet supplied and leftovers, collected and weighed once daily, during the collection period. Leftovers and food offered, elephant grass silage and mesquite pod meal, were quantified and sampled from the 11st to the 15th day of collection and stored in plastic bags at -20°C for later analysis.

For each treatment, we determined the apparent digestibility using the technique of total collection of feces over the five days of data collection. After weighing the feces each day, a 10% sampling was done for subsequent pre-drying and for obtaining a composite sample proportional to the dry weight of samples taken at each collection day per animal and experimental period. In the same period, we also collected total urine using plastic buckets covered with screen. Each bucket contained 100 mL 20% H_2SO_4 to avoid possible volatilization and decomposition of nitrogenous compounds. Samples around 10% of total urine weighed daily was withdrawn to obtain a composite sample (for each animal and each experimental period), stored in labeled plastic pots at -10°C for later analysis. The total nitrogen content was determined by the micro Kjeldahl method in composite samples of feed supplied, leftovers, feces, and total urine (AOAC, 1998).

Nitrogen (N) balance was calculated as: N balance = supplied N - (leftovers N + feces N + urine N), where supplied N, leftovers N, feces N and urine N represent the average daily amount of nitrogen in food supplied, in leftovers, in feces and in urine, respectively.

At the end of the experiment, samples of leftovers, elephant grass silage and feces collected from each animal were thawed at room temperature for 4h. Later, they were pre-dried in a forced ventilation oven at 60°C and processed in a knife mill with 1 mm sieve for subsequent laboratory analysis of dry matter (DM), organic matter (OM), mineral matter (MM), crude protein (CP) and ether extract (EE), which were determined according to the recommendations of the Association Of Official Agricultural Chemists (AOAC, 1998) and neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, hemicellulose and lignin (H_2SO_4 72% p/p) according to Van Soest et al. (1991).

Total carbohydrate content (TC) was estimated according to Sniffen, O'Connor et al. (1992) using the following formula: TC = 100 - (%CP + % EE + % MM).

Non-fiber carbohydrate content corrected for ash and protein (CNFcp) was calculated as proposed by Hall (2003), namely: NFC = (100 - %NDF - %CP - % EE - % MM).

Table 1 presents the chemical composition of MPM and elephant grass silage.

Table 1. Chemical composition of feedstuffs and experimental diets.

Nutrients	Feedstuffs	
	MPM	Elephant grass silage
DM (%DM)	88.90	30.14
OM (%DM)	97.94	97.10
MM (%DM)	2.05	2.54
CP (%DM)	12.01	6.47
NDFcp (%DM)	29.49	72.08
ADF (%DM)	27.51	70.96
CEL (%DM)	24.38	59.50
HCEL (%DM)	3.83	6.73
EE (%DM)	1.16	2.81
NDIN (%DM)	0.12	0.13
ADIN (%DM)	0.04	0.10
LIG	5.30	12.12
TC (%DM)	84.78	88.18
NFCcp (%DM)	53.44	10.48

DM: dry matter, OM: organic matter, MM: mineral matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, CEL: cellulose, HCEL: hemicellulose, EE: ether extract, NDIN: neutral detergent insoluble nitrogen, ADIN: acid detergent insoluble nitrogen, LIG: lignin, NFCcp: non-fiber carbohydrate corrected for ash and protein.

Data of intake, digestibility and nitrogen balance were assessed using analysis of variance and regression using the SAS package (SAS, 2004).

Results and discussion

There was an increasing linear effect ($p < 0.05$) of the different levels of mesquite pod meal replacing elephant grass silage on the intake of DM, OM, CP, ADF, NDF, NFC and TC (Table 2).

Table 2. Average daily intake (g day^{-1}) of dry matter and nutrients according to the replacement of elephant grass silage with mesquite pod meal (MPM).

Nutrients	MPM (%DM)					P-value	
	0	15	30	45	CV%	L	Q
DM	599.6	729.0	887.3	1034.6	13.7	0.0001[1]	0.8593
OM	594.2	692.6	878.7	984.8	14.3	0.0001[2]	0.9297
CP	42.8	58.0	79.3	98.7	13.3	0.0001[3]	0.7244
EE	40.4	39.9	41.4	39.8	15.9	0.9963[4]	0.8285
ADF	408.8	443.8	479.7	494.9	14.7	0.0301[5]	0.7307
NDF	421.4	463.1	502.6	526.9	15.5	0.0174[6]	0.7814
NFC	65.4	139.3	232.2	345.7	25.8	0.0001[7]	0.2048
TC	449.7	565.1	696.1	859.4	21.7	0.0001[8]	0.6055

DM: dry matter, OM: organic matter, CP: crude protein, EE: ether extract, ADF: acid detergent fiber, NDF: neutral detergent fiber, NFC: non-fiber carbohydrate, TC: total carbohydrate, L: linear effect, Q: quadratic effect. *($p < 0.05$) **($p > 0.01$) ***($p < 0.001$); [1]$\hat{Y} = 593.150 + 9.756^{***}X$ ($r^2 = 0.99$); [2]$\hat{Y} = 587.180 + 9.179^{***}X$ ($r^2 = 0.98$); [3]$\hat{Y} = 40.7301 + 1.278^{***}X$ ($r^2 = 0.99$); [4]$\hat{Y} = 40.390$; [5]$\hat{Y} = 411.450 + 1.771^{*}X$ ($r^2 = 0.97$); [6]$\hat{Y} = 423.980 + 2.299^{**}X$ ($r^2 = 0.98$); [7]$\hat{Y} = 65.266 + 6.150^{***}X$ ($r^2 = 0.99$); [8]$\hat{Y} = 457.350 + 8.249^{***}X$ ($r^2 = 0.99$).

The increase in DM intake was related to the greater acceptability of the diet by the animals with increasing levels of MPM replacing elephant grass silage, as the meal has better nutritional quality and palatability compared with the silage. The consumption of silage is usually low when compared to dry forages because of the acids produced by the same, the low crude protein and possible problems in fermentation.

There was also a linear increase in the intake of OM ($p < 0.05$) reflecting the increased DM intake. Even with a reduction in NDF and ADF ($p < 0.05$) with the addition of MPM in the diets, their contents have risen, since the MPM presents NDF and ADF associated with a higher DM intake according to the replacement. These results corroborate those reported by Batista et al. (2006) and Rêgo et al. (2011) which included MPM in elephant grass silage and observed a linear decrease ($p < 0.05$) in NDF and ADF of the experimental diets.

The DM intake by sheep was positively related to the intake of NDF, since although the NDF content in the diet had been relatively high, DM intake was not reduced. Decreased DM intake is expected due to the high levels of dietary NDF, once NDF has low ruminal degradation and slow rate of passage through the reticulo-rumen. However, when the fiber is digestible, this stimulates consumption by increasing the rate of passage, so that there is an increase in feeding efficiency. Pereira et al. (2013) reported that with the use of forage containing fiber with physical effectiveness and low digestibility, the addition of MPM promoted increased dry matter intake efficiency. Probably the increase in NDF intake is associated with higher degradability and smaller particle size of the MPM, favoring fermentation and stimulating DM intake.

In this way, Bezerra et al. (2004) studied the influence of fiber size on the retention time and the apparent digestibility in diets for dairy cows, and stated that reducing food particle size and increasing surface area, the digestion rate would increase by improving the access of microbial enzymes. Similarly, Morais et al. (2006) included soybean hulls in the diet of sheep and found an increased digestibility of nutrients related to smaller particle size.

According to Van Soest (1994) and Maggioni et al. (2009) dry matter intake is positively correlated with NDF, when it is in the feed between 55 and 60% DM, with increased consumption with increased NDF in the diet. Nevertheless, a negative correlation is observed when NDF exceed 60% of DM, promoting reduced consumption. Other aspects must be taken into consideration, such as the quality of the NDF in the diet and characteristics of the animal.

As with the DM, NDF and ADF, we also observed a positive linear effect ($p < 0.05$) for CP intake (Table 2), due to the higher CP content of mesquite pods when compared to elephant grass silage.

The replacement levels of elephant grass silage with MPM did not influence ($p > 0.05$) EE intake, as it shows low concentration in MPM and also in the elephant grass silage.

The intake of NFC and TC also increased linearly ($p < 0.05$) as MPM was added to the diets, because the MPM has a higher concentration of CNF compared to the elephant grass silage.

The digestibility coefficients of DM, OM and CP increased linearly ($p < 0.05$) with increasing levels of the MPM, due to the increase in DM intake and other nutrients (Table 3).

Table 3. Coefficients of apparent digestibility of dry matter and nutrients according to the replacement of elephant grass silage with mesquite pod meal (MPM).

Nutrients	Level of MPM (%)					P-value	
	0	15	30	45	CV%	L	Q
ADCDM	45.4	47.1	50.5	54.0	7.2	0.0001[1]	0.4786
ADCOM	52.5	50.8	55.6	56.8	9.8	0.0501[2]	0.4436
ADCCP	39.3	45.3	51.0	53.4	14.3	0.0001[3]	0.4286
ADCEE	59.8	58.2	49.7	48.1	18.3	0.0079[4]	0.9966
ADCADF	42.2	33.4	34.4	31.4	24.4	0.0223[5]	0.2739
ADCNDF	44.2	34.4	32.7	31.7	11.5	0.0001[6]	0.4800
ADCTC	94.3	94.7	95.1	95.7	0.9	0.0019[7]	0.6713
ADCNFC	94.0	98.2	99.0	99.2	3.9	0.0088[8]	0.1279

ADCDM: apparent digestibility coefficient of dry matter, ADCOM: apparent digestibility coefficient of organic matter, ADCCP: apparent digestibility coefficient of crude protein, ADCEE: apparent digestibility coefficient of ether extract, ADCADF: apparent digestibility coefficient of acid detergent fiber, ADCNDF: apparent digestibility coefficient of neutral detergent fiber, ADCTC: apparent digestibility coefficient of total carbohydrates, ADCNFC: apparent digestibility coefficient of non-fiber carbohydrates, L: linear effect, Q: quadratic effect; ⋆ ($p < 0.05$) ⋆⋆($p > 0.01$) ⋆⋆⋆($p < 0.01$); [1]$\hat{Y}$ = 44. 884+0.195⋆⋆⋆X ($r^2 = 0.97$); [2]$\hat{Y}$= 51. 294+0. 117⋆⋆X ($r^2 = 0.68$); [3]$\hat{Y}$= 40.065+0.320⋆⋆⋆X ($r^2 = 0.96$); [4]$\hat{Y}$= 60. 542-0.290⋆⋆⋆X ($r^2 = 0.90$); [5]$\hat{Y}$= 39.964-0.201⋆⋆X ($r^2 = 0.87$); [6]$\hat{Y}$= 42.6385-0.3154⋆⋆X ($r^2 = 0.95$); [7]$\hat{Y}$= 94. 307+0.030⋆⋆⋆X ($r^2 = 0.98$); [8]$\hat{Y}$= 95. 176+0. 109⋆⋆⋆X ($r^2 = 0.75$).

The increased digestibility of CP may be related to low levels of ADIN and NDIN in MPM, with greater nitrogen availability to rumen microorganisms. There was a reduction in the digestibility of EE and ADF ($p < 0.05$) with reductions estimated at 0.30 to 0.25% for each unit MPM added, respectively.

NDF digestibility decreased linearly ($p < 0.05$), as the fiber of MPM is short, it may have affected the digestibility of this fraction by increasing the rate of passage through increased consumption of DM.

The reduced digestibility of EE may be a result of the lower content in the MPM. Associated to this, the microbial synthesis and epithelial desquamation may have contributed to the increased flow of lipids in the intestine relative to their intake.

As the elephant grass silage was replaced with MPM, digestibility of TC and NFC increased linearly ($p < 0.05$), because MPM has lower NDF content and higher content of soluble carbohydrates, which are more digestible, thus increasing the digestibility of these carbohydrate fractions. MPM, according to Figueiredo et al. (2007) shows contents of NFC at 59.92% and of TC similar to the concentrate, 87.01%. For MPM, Valadares Filho (2006) also reported average values of 54.16% soluble carbohydrates in the DM.

The inclusion of MPM in the diet provided an increase in nitrogen intake ($p < 0.05$) (Table 4) due to increased DMI associated with higher content of crude protein in diets containing MPM, which also influenced the increase of nitrogen retained.

Table 4. Nitrogen balance of sheep fed diets containing different levels of replacement of elephant grass silage with mesquite pod meal (MPM).

Item	Level of MPM (%)				CV(%)	P-value	
	0	15	30	45		L	Q
NI (g day^{-1})	6.69	9.28	12. 69	15.86	12.41	0.0001[1]	0.021
NF (g day^{-1})	7.58	8.23	8.75	9.52	6.55	0.0001[2]	0.063
NU (g day^{-1})	1.54	1.83	2.01	1.27	34.68	0.3143	0.062
N BAL	-2.43	-1.69	1.91	3.94	702.54	0.0001[3]	0.2529

NI: Nitrogen ingested, NF: Nitrogen in feces, NU: Nitrogen in urine, N BAL: Nitrogen balance, L: linear effect, Q: quadratic effect; ⋆ ($p < 0.05$) ⋆⋆($p > 0.01$) ⋆⋆⋆($p < 0.01$); [1]$\hat{Y}$ = 6.649950+0.206050⋆⋆⋆X ($r^2 = 0.99$); [2] $\hat{Y}$ = 7.75721+0.042335⋆⋆⋆X ($r^2 = 0.99$); [3]$\hat{Y}$ = -2.298031+0.151749⋆⋆⋆X ($r^2 = 0.94$).

Nitrogen excretion in feces also increased linearly ($p < 0.05$), with higher average values verified in animals fed diets with replacement level of 45%, a fact related to the higher consumption of nitrogen.

Nitrogen excretion in urine was not affected by the addition of mesquite meal to the diets. Thus, the statement that the rate of protein degradation exceeds that of fermentation of carbohydrates, large amounts of nitrogenous compounds in the form of urea can be eliminated via urine, reported by Van Soest (1994) does not apply in this study probably due to the good synchronization between the protein degradation and dietary energy.

Although nitrogen excretion in urine is higher with increasing concentration of crude protein in the diet and greater nitrogen intake by the animal (Van Soest, 1994), this did not occur in this study. A similar result was obtained by Alves et al. (2012) who associated the mesquite pod meal with urea levels and not noticed influence on urinary excretion of N, probably because of the isonitrogenous diets used, consisting of the same proportion of mesquite pod meal, differently from those of the present study.

The animals fed diets with 30 and 45% of MPM showed positive nitrogen balance ($p < 0.01$) probably due to the increase intake of CP and energy, which met the requirements of metabolizable protein of animals provided by the higher efficiency in the use of ruminal nitrogen and tissues, allowing for a positive change in body weight of 0.05 and 0.06 kg day^{-1} for the abovementioned levels. Whereas for 0 and 15% replacement levels, we found a negative variation of -0.08 and -0.02 kg day^{-1}, respectively.

Conclusion

The addition of mesquite pod meal up to 45% provides increased intake of dry matter and nutrients. At the same time, the addition of mesquite pod meal reduced the digestibility of ether extract and neutral detergent fiber. The addition of 30 and 45% of mesquite pod meal in a forage-based diet for sheep positively influences nitrogen balance, representing a viable alternative in critical periods of the year for not causing weight loss of the animals.

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